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Mr. Chairman, I appreciate the opportunity to testify on the subject of the relationship between of oil shale technology and issues raised in demonstration and commercialization programs.

Late in 1976 the Congressional Budget Office (CBO) performed an analysis of energy research, development, demonstration, and commercialization . That analyis is summarized in a CBO Budget Issue Paper entitled "Energy Research, Development, Demonstration and Commercialization". It is the mission of the CBO to provide nonpartisan analysis of policy and budgetary issues before the Congress. Our paper is intended to fulfill this mission with respect to these particular aspects of the general issue of energy.

The case of oil shale technology is not the only opportunity for the federal government to address the questions of demonstration of new energy technologies, or of enhancing commercial implementation. For instance, in passing the federal Non-nuclear Energy Research and Development Act of 1974, the Congress declared that the purpose of the Act was "...to establish and vigorously conduct a comprehensive, national program of basic and applied research and development, including ...demonstrations of practical applications..."

In addition, in the last session of Congress, bills were considered to provide incentives for the commercialization of synthetic fuels.

This morning I would like to focus my remarks on the process which leads from research largely in the laboratory, to development on operating scale, to demonstration, and finally to commercialization of a new technology. There are some generalizations about this process that I would like to share with the Committee, and then I would like to relate these to several issues in oil shale technology.

The R,D,D, and C process, involves the creation, accumulation, dissemination, and use of knowledge. This process relies on two disciplines--science and engineering--in the early stages, and combines these with economics and finance in the later stages.

Scientists and engineers, by the nature of their disciplines, are likely to focus on individual segments of the process, such as the scientific basis and feasibility of fusion or the design of less expensive or more reliable synthetic fuel plants. Economists and financiers are concerned more with profitability and risk in the marketplace.

Congress I am sure will take a broad view of the many factors that make possible the completion of the process, including the desirability of a technology itself, budgets for support (and the competing claims on those budgets), and the extent and timing of participation by the private sector.

As any energy technology (solar, nuclear, etc.) moves from the research stages through development to demonstration and commercialization, it will at each step make varying demands upon scientific and engineering personnel, funding, and market incentives. The criteria of success will also vary at each of the four stages. Progress will depend on what has already been learned, what can be achieved in any particular stage, and any major uncertainties that might surround the project at a given stage. It is this information component that ought to determine how quickly decisions can be made about ultimate disposition of the technology.

The distinction between successive stages in the R,D,D, and C, process are rarely clear. Indeed, the process can be viewed as a continuous one, in which the nature and volume of information available is constantly--if often almost imperceptibly--changing. As the information changes, so do the questions which must be asked next. The first questions tend to be scientific, but as the technology matures, engineering, economic, and institutional questions become increasingly important.

Several technologies may produce energy from oil shale. Each one is at a different point in the R,D,D, and C continuum, and thus support should be tailored to fit each unique technology. It's also important where possible not to foreclose one technology support for another. The following discussion of each stage development may help to clarify their relation to each other and to the entire process.

RESEARCH AND DEVELOPMENT

Research and development is generally designed to gather information about theoretical and technical uncertainties and to carry the investigation to a point where it is possible to determine the technical feasibility of a technology or process.

The distinction between research and development is difficult to make, however, and with the exception of certain "basic research" programs, is rarely made in practice. Research is now being carried out in the fusion program, for example, to show whether it is possible to extract more energy from the process than it consumes. This break-even point will determine, at a very basic level, whether fusion can possibly become a source of energy. In the solar area, for another example, photovoltaic (light to electricity) materials can convert sunlight to energy. However, to become an economic energy source, the photovoltaic process requires the production of huge quantities of material that have uniform, reliable characteristics. Techniques for manufacturing this material in volume and at reduced costs need to be developed.

With respect to production of oil or gas from shale research is continuing on two fronts--techniques to extract energy from the shale while it remains in the ground--in situ processing--and on advanced methods of retorting shale above ground.

The information gained in this research and development stage about basic feasibility, about subsidiary problems like materials performance, and about necessary design features will determine whether and how a demonstration is to be performed.

DEMONSTRATION

It is appropriate to begin the demonstration stage when basic uncertainties have been resolved and the new information gained indicates that the demonstration will generate information about other remaining uncertainties associated with a much larger scale effort. For energy technologies, such uncertainties are likely to be economic, environmental, or institutional in nature. The point of constructing a demonstration project at near-commercial scale is not simply to increase its size but to find answers to still unresolved questions that can only be found with a model constructed on this larger scale. For example, environmental impacts will be more extensive and measurable, process control, product quality and reliability can be determined the institutional impediments may be more apparent, and the costs are likely to be far greater than those incurred in earlier stages.

All of these uncertainties--economic, environmental, institutional--need not exist in order to justify a demonstration project. Each demonstration will have a specific combination of factors, some of which are well known and some of which pose substantial uncertainties. In general, technical feasibility is, or should be, better known than other factors, because feasibility relates more closely to technological principles (e.g., the laws of physics) that generally are not altered by enlargement; and because feasibility can be tested at a smaller scale more quickly and less expensively.

The demonstration project can be designed to address these problems as well as the viability of the technology at a scale in which the individual units are of a size close to what they would be in commercial operation. Indeed, if a new energy technology were known to be feasible and reliable; if the cost of its operation at a commercial scale were well understood; if its environmental effects were well catalogued and techniques for mitigating such effects were well in hand; if its price were competitive with alternative sources; and if this knowledge were perceived by users and suppliers, there would be no reason to undertake a demonstration. The technology could be put into commercial production immediately.

A recent study by the Rand Corporation, concluded that the elements of a successful demonstration regularly are: (1) a technology well in hand; (2) cost and risk-sharing with nonfederal participants; (3) project initiatives from nonfederal sources; (4) the existence of a strong industrial system for commercialization; (5) inclusion of all participants needed for commercialization; (6) absence of tight time constraints.

Those conclusions are relevant to the present discussion in several ways. First, it is clear that an important factor in the success of a demonstration is that the technology be ready to leave the R and D stage (i.e., uncertainties about technical feasibility are resolved). A demonstration designed to uncover a large amount of new information about technical feasibility or environmental effects is less likely to provide a system ready

for commercialization and could more appropriately be carried out as an R and D project. Second, demonstration projects should include major private sharing in the initiation, planning, and funding to create the conditions--particularly the existence of direct experience--which enhance the likelihood of ultimate commercialization.

These findings would indicate that complete funding by the federal government, with a dominant federal planning and management presence, makes ultimate commercial success less likely.

COMMERCIALIZATION

The final stage in the progression of a new technology is its commercialization.

Most technological innovation, of course, needs no government intervention to encourage commercial adoption if an appropriate market exists. The market rewards successful innovation with profits and punishes failures with losses. Government action to commercialize a technology becomes necessary only when two conditions exist simultaneously: (a) a promise of substantial benefit to the nation or society from that technology, and (b) a market environment that does not encourage its adoption.

The kind of marketplace obstacle to commercialization varies with the technology to be introduced; therefore the type of government action necessary to remove the obstacle will vary. If, for example, the obstacle is not technical feasibility or costs, but the inability of the private sector to raise large amounts of investment capital, then a government commercialization program including

direct grants, loans, or loan guarantees might be appropriate. If, on the other hand, the obstacle were the availability of competing energy sources which are lower priced at the time of commercialization of the new technology (although the fear that they will become higher priced later or run out entirely may well cause the need for the new technology) then, some form of price subsidies might be helpful. However, government intervention to reduce one type of obstacle--lack of capital or non-competitive prices may not be appropriate for the other and may even be counterproductive.

There are precedents for government provision of commercialization incentives. The nuclear power industry, for example, was helped to the commercialization stage with insurance incentives to assist in capitalization (the Price-Anderson Act).

Costs are likely to be the largest at the commercialization stage because the scale of effort is largest. This does not necessarily mean that the cost to the government will be proportionately high, because private industry may be more willing to accept an important share of costs at this stage when profits may soon be realized.

I have focused on the information requirements that change from one stage to another, because it is largely to improve that information which justifies the support. However, the federal role also changes from grants and performance of research at the early stages to cost sharing or ownership for demonstration to loan guarantees, price supports and/or cost sharing at the commer-

cialization stage. Thus knowing what is the intent of a specific project can help to determine appropriate stages, sizes, costs, and federal roles.

How do these considerations affect the issue of oil shale commercialization? First they suggest some specificity is needed in dealing with the various oil shale technologies under development, because the technologies are not at the same points in development. Second it is important to understand the uncertainties remaining in specific oil shale technologies.

The first question to ask is with respect to technical feasibility because if questions remain about actually producing oil the process is still in a stage of research and development. Since the in situ technology seems less mature than most surface retorting, processes and the committee is in a position to get answers to this, then it may be more appropriate at this time to encourage pilot scale development of some aspects of in situ.

Methods of surface retorting are more advanced because methods of strip and deep mining use existing technologies, and several methods of processing the shale above ground have been demonstrated to some extent. If the operators of these processes, ERDA, or private industry feel that technical feasibility is no longer an issue, then either a larger demonstration, or possibly commercialization could be in order.

For those technologies in which technology feasibility uncertainties are resolved, a large scale demonstration may be appropriate to resolve other uncertainties. Those unknown at the

demonstration stage for oil shale are likely to include: control of air emissions, the intrusion of chemicals into ground water, disposal of spent shale, revegetation of mined areas, and use of water; operation of a much larger facility, to test operational control and quality impacts on the regional economy. If many of these remain uncertain for oil shale technologies, then a demonstration could be designed to resolve or determine them.

It will only be when all of the foregoing issues are resolved that commercial implementation will become appropriate. The uncertainties then remaining will be related to market factors. Many proponents argue that the economic risks are great and federal suppport of some sort is required. For oil shale the uncertainties would include the market price of alternate energy sources (e.g. imported oil) and the availability of large amounts of capital financing. The choice of mechanism for federal support would depend on which of the uncertainties--capital difficulties or noncompetitive price-- were the obstacle to implementation.

In summary Mr. Chairman, the development of oil shale technologies and the federal role for demonstration and commercialization, depend on answers to a series of questions which only the experts can give. I am not suggesting that everything needs to be known about everything before beginning, that could delay progress indefinitly. Rather it is the resolution of major uncertainties that may still remain such as where air emissions can be brought to acceptable levels or the level of water use that determine whether a transition can be made from demonstration to commercialization.

The same applies to attractive processes now in R and D that should not be allowed to wither on the vine. The prudent course both for budgets and success may be to address the questions carefully because the need for energy from these technologies does not unambiguously determine the type or level of federal support.

Mr. Chairman I am happy to have been able to speak before you, I would welcome any questions you may have.